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# Effects of progressive increase in body weight on lung function in six groups of body mass index

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## Summary

**Objective:** To evaluate the effects of the progressive increase in body weight on lung function by oxygen peripheral saturation, spirometry and maximal respiratory pressures in different degrees of obesity. **Methods:** Cross-sectional study including 140 patients in clinical and surgical evaluation for obesity treatment. The selected patients were divided into six groups of body mass index (BMI), including a control group of non-obese and a subdivision for the morbidly obese into three subgroups. **Results:** Significant differences were demonstrated between the groups regarding oxygen peripheral saturation ($SpO_2$) ($p \leq 0.001$), forced vital capacity (FVC) ($p \leq 0.002$, $p \leq 0.02$) and forced expiratory volume in one second (FEV1) ($p \leq 0.001$, $p \leq 0.03$) in relative and absolute values, respectively. Group VI (BMI ≥ 50.9 kg/m²) showed significant differences ($SpO_2$, FVC and FEV1) when compared with the other groups (except group V) and group V (BMI ≥ 45 to 49.9 kg/m²) with the group control. The other variables (FEV1/FVC ratio, forced expiratory flow 25-75 [FEF25-75] and maximal respiratory pressure) did not show any statistical differences. **Conclusion:** Lung function is influenced by the progressive increase in BMI, with changes in lung function better demonstrated when BMI ≥ 45 kg/m²; these changes are more evident when BMI > 50.9 kg/m².

**Keywords:** Spirometry; respiratory function tests; obesity; morbid obesity; cross-sectional studies; body mass index.

Study conducted at Universidade Federal de Sergipe, Hospital Universitário, Aracaju, SE, Brazil

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## Introduction

The alarming worldwide increase in the prevalence of obesity has been a concern to the World Health Organization (WHO), being one of the most serious public health problems in recent years, with threatening projections for the 21st century[1].

In Brazil, similar to developed countries, the prevalence of obesity has shown a significant increase in all age groups, especially in the female sex[2]. Obesity prevention and control have been a priority for the WHO due to the fact that obesity is a systemic disease associated with various comorbidities, being an important independent risk factor for chronic diseases (cardiovascular diseases, diabetes, musculoskeletal disorders and some cancers), with high risk of premature death[1,3].

Obesity promotes deterioration of respiratory mechanics by decreasing the chest expansibility due to the increase in adipose tissue in the chest wall and abdominal cavity. That increases and impairs diaphragmatic mobility, causing decrease in lung compliance and chest wall, resulting in decreased pulmonary volumes and inspiratory muscle overload. The decrease in lung ventilation may lead to peripheral lung occlusion, ventilation-perfusion abnormalities and arterial hypoxemia[3-6].

The worsening in lung function in obese patients is associated with increased morbidity and mortality, similar to other diseases such as cancer, cardiovascular and chronic respiratory diseases and heart attack[3,4]; however, very often the influence of obesity on respiratory disorders goes unrecognized[3-6].

Lung function tests are essential for the management of patients with respiratory disorders, as well as those with potential to develop them, providing objective data on lung function and determining their correlation with the patient's clinical complaints[7,8].

Spirometry is the most frequent and useful lung function test carried out in clinical practice[9]. The peripheral oxygen saturation ($SpO_2$) performed by pulse oximetry is a noninvasive, safe, practical and inexpensive method. It is a sensitive indicator of abnormal gas exchange and can be used as a screening test for arterial gasometry[8,10].

The respiratory muscle strength assessment through maximal respiratory pressure measurement has been incorporated into clinical practice. The MIP (maximum inspiratory pressure) is an index of diaphragm strength, while the MEP (maximal expiratory pressure) measures the strength of the abdominal and intercostal muscles[6,11,12].

Previous studies of pulmonary function in obese patients are limited to assessing functional changes in three obese classes, considering the morbidly obese (BMI $\geq$ 40 kg/m²) as a single group, according to the WHO classification by BMI (body mass index): underweight $\leq$ 18.5 kg/m²; normal from 18.5 to 24.9 kg/m²; overweight: 25 to 29.9 kg/m²; obesity grade I: 30 to 34.9 kg/m²; obesity grade II : 35 to 39.9 kg/m² and obesity grade III $\geq$ 40 kg/m²)[13-15].

The aim of this study was to evaluate the effects of the progressive increase in body weight on lung function by spirometry, $SpO_2$, MIP and MEP in different degrees of obesity. The group of morbidly obese patients has been subdivided into three subgroups to better demonstrate the effect of the progressive increase in BMI on the respiratory functional variables studied.

## Methods

This is a cross-sectional study carried out at the Outpatient Clinic of Universidade Federal de Sergipe (UFS), in the city of Aracaju, Sergipe. Data were collected between January and December 2007. The study was approved by the Ethics Committee in Research of the UFS (CAAE-0050.0.107.000-07) and a signed free and informed consent form was obtained from all patients.

The sample was selected among patients undergoing clinical and surgical evaluation for the treatment of obesity in the obesity outpatient clinics of Hospital São Lucas and UFS, where the clinical assessment and lung function tests were conducted by an assistant pneumologist. We selected a control group of 26 healthy subjects with no respiratory symptoms, who had normal lung function according to the criteria of the Brazilian Guidelines for Lung Function Test[16], consisting of volunteers (family members and friends of patients, healthcare professionals).

The 140 selected individuals were divided into six groups according to BMI level: Group I: 26 (normal weight and overweight) with BMI: 18.5 to 29.9 kg/m²; Group II: 18 individuals (class I obesity) with BMI 30 to 34,9 kg/m²; Group III: 24 subjects (class II obesity) with BMI 35 to 39.9 kg/m²; Group IV: 30 patients (class III obesity) with BMI 40 to 44.9 kg/m²; Group V: 23 individuals (class III obesity) with BMI 45 to 50.9 kg/m²; Group VI: 19 individuals (class III obesity) with BMI $\geq$ 51 kg/m².

Patients aged 18 years and older were included. All patients from the obese group under evaluation for surgical treatment of obesity (groups III to VI) had previously tried at least three clinical treatments, experiencing failure and frustration. They were compensated from the clinical point of view with diet and/or drugs and had been approved to undergo the surgical treatment of obesity.

The exclusion criteria were used for patients with acute or chronic pulmonary disease, unable to perform the lung function tests, those with neuromuscular disease, heart failure, severe or poorly controlled hypertension, chronic kidney disease, severe systemic disease, systemic corticosteroid use, decompensated *diabetes mellitus*, current smokers or former smokers who had smoked more than 10 packs/year.

Due to medical indication, the obese patients were submitted to chest x-ray, electrocardiogram, echocardiogram and laboratory tests during the preoperative evaluation.

Those who had never smoked were considered non-smokers and ex-smokers those who had stopped smoking for at least six months and had smoked less than 10 packs/year. Active smokers were those who consumed tobacco products at any amount at the time of the study or over the last six months.

Regarding physical activity, individuals were considered non-sedentary when they performed regular physical activity at least three times a week, with a minimum duration of 30 minutes. Sedentary were considered those who did not perform any physical activity or did so for shorter periods of time.

Body weight was measured with the individual wearing light clothes and no shoes and height was obtained using an anthropometer attached to the scale that met the criteria for measuring weight of morbidly obese patients. BMI was calculated as weight in kilograms divided by height in meters squared.

After the patient had been sitting at rest for at least ten minutes, $SpO_2$ was measured using a Medical Onyx II 9500 portable digital oximeter (Nonin, Plymouth, Minneapolis, USA) in one of the fingers, without enamel, after a waiting period of at least two minutes until the reading. Then, with the patient in the sitting position and using a nose clip, lung function tests were sequentially performed: MIP, MEP and spirometry.

The MIP was measured from the residual volume and MEP from total lung capacity, with a minimum of five maneuvers being performed for each of them and using the highest value. The reference equation for the maximal respiratory pressures was expressed as a percentage of normality for the Brazilian population, according to the equation by Neder et al.[17]; for spirometry, the equation of references by Hankinson[18] was used, with the maneuvers being performed in accordance with current recommendations by the SBPT[16]. During the spirometric test, forced expiratory maneuver was performed at least three times, after which the best one was chosen.

Spirometry was performed using a computerized spirometer (model Microlab-3500) and maximal respiratory pressures using a digital Micro Respiratory Pressure Meter manovacuometer (Micro RPM), both from Micro Medical Ltd., Kent, UK.

The variables analyzed were sex, age, ethnicity, height, smoking status, BMI, physical activity level, $SpO_2$, MIP, MEP ($cmH_2O$), FVC, FEV1, FEF25-75, FEV1/FVC ratio, in absolute and relative values.

Statistical analysis was performed using the Statistical Package for Social Sciences, release 13 (SPSS Inc., Chicago, IL, USA). Continuous variables were described as mean and standard deviation and categorical variables were summarized by means of simple and relative frequencies, and the Chi-square or Fisher's exact test was used as appropriate. The comparison between the different BMI categories was performed using one-way ANOVA followed by Tukey's post-test and calculation of 95% CI. Two-tailed tests were used and the level of statistical significance was set at $p < 0.05$.

## Results

A total of 140 patients with a mean age of 36.4 ± 11.2 years was evaluated, ranging from 18 to 63 years, of which 84 (60.0%) were females. Regarding ethnicity, 74 (52.9%) were Caucasians. The mean BMI was 39.91 ± 10.57 kg/m² (range 19.3 to 65.6 kg/m²), with a significant difference between the groups ($p < 0.001$). The groups had a homogeneous distribution regarding sex, age, ethnicity, height, smoking status and physical activity (Table 1).

Table 2 compares the spirometric variables, maximal respiratory pressures and oxygen saturation in the six groups. The mean $SpO_2$ was 97.18 ± 1.6%, ranging from 89% to 100%, with a significant difference between the groups ($p \leq 0.001$).

Group VI showed lower $SpO_2$ with significant differences with the other groups (group I: $p \leq 0.006$ and 95% CI: 0.9 to 3.4, group II: $p \leq 0.01$ and 95% CI: 0.2 to 3.0; group III: $p \leq 0.02$ and 95% CI: 0.2 to 2.8), except for group V, which showed lower $SpO_2$, with significant differences with groups I ($p \leq 0.004$ and 95% CI: 0.6 to 3.0) and IV ($p \leq 0.003$ and 95% CI: 0.03 to 2.4). Group IV showed a homogeneous distribution with groups I, II and III (Table 2, Figure 1).

The mean FVC was 3.72 ± 0.87 liters in absolute values, ranging from 1.74 to 5.97 liters and in relative values, 88.97 ± 0.12%, ranging from 48% to 119%. As for FEV1, the mean absolute value was 3.03 ± 0.72 L, ranging from 1.34 to 5.36 L and the relative value was 88.55 ± 11.41%, ranging from 51% to 119%.

The groups showed statistical differences regarding the mean FVC in absolute and relative values ($p \leq 0.02$, $p \leq 0.002$, respectively), with a progressive reduction in FVC between the groups. Regarding absolute values of FVC, only Group I was superior to Group VI ($p \leq 0.008$ and 95% CI: 0.15 to 1.63). As for relative values of FVC, Group VI was statistically lower than the groups: I ($p \leq 0.001$ and 95% CI: 10.4 to 29.4), Group II ($p \leq 0.006$ and 95% CI: 2.6 to 23.3), Group III ($p \leq 0.006$ and 95% CI: 2.4 to 21.7) and Group IV ($p \leq 0.003$ and 95% CI: 3.0 to 21.4). Group V was statistically lower than Group I ($p \leq 0.005$ and 95% CI: 2.3 to 20.4) (Table 2, Figure 1).

The mean values of FEV1 differed significantly between the groups in absolute and relative values ($p \leq 0.03$, $p \leq 0.001$, respectively), with a progressive decrease in FEV1 between the groups. In absolute FEV1 values, only Group I was statistically higher than Group VI ($p \leq 0.01$ and 95% CI: 0.09 to 1.34). It was also observed that relative values in Group VI were statistically lower than the groups: I ($p \leq 0.001$ and 95% CI: 8.9 to 27),

**Table 1** – Distribution of demographic characteristics, physical activity and smoking status, stratified by BMI

| Variable (n) | G I (26) | G II (18) | G III (24) | G IV (30) | G V (23) | G VI (19) | p |
|---|---|---|---|---|---|---|---|
| Gender[1] n (%) | | | | | | | |
| Male | 14 (53.8) | 6 (33.3) | 8 (33.3) | 10 (33.3) | 10 (43.5) | 8 (42.1) | 0.61 |
| Female | 12 (46.2) | 12 (66.7) | 16 (66.7) | 20 (66.7) | 13 (56.5) | 11 (57.9) | |
| Age (years)[2] | 34.3 ± 11.7 | 42.6 ± 12.6 | 35.6 ± 11.2 | 35.1 ± 9.8 | 34.6 ± 10.7 | 39.2 ± 10.5 | 0.12 |
| Ethnicity[1] | | | | | | | |
| Caucasian | 14 (53.8) | 8 (44.4) | 14 (58.3) | 18 (60.0) | 11 (47.8) | 9 (47.4) | 0.86 |
| Non-Caucasian | 12 (46.2) | 10 (55.6) | 10 (41.7) | 12 (40.0) | 12 (52.2) | 10 (52.6) | |
| Height (meters)[2] | 1.66 ± 0.08 | 1.65 ± 0.07 | 1.65 ± 0.10 | 1.65 ± 0.08 | 1.67 ± 0.08 | 1.65 ± 0.11 | 0.99 |
| Smoking status[3] | | | | | | | |
| No smoker n (%) | 25 (96.2) | 12 (66.7) | 18 (75.0) | 19 (63.3) | 18 (78.3) | 14 (73.7) | 0.06 |
| Ex-smoker n (%) | 1 (3.8) | 6 (33.3) | 6 (25.0) | 11 (36.7) | 5 (21.7) | 5 (26.3) | |
| Physical activity[3] | | | | | | | |
| Sedentary n (%) | 19 (73.1) | 13 (72.2) | 18 (75.0) | 26 (86.7) | 20 (87.0) | 17 (89.5) | 0.49 |
| Non-sedentary n (%) | 7 (26.9) | 5 (27.8) | 6 (25.0) | 4 (13.3) | 3 (13.0) | 2 (10.5) | |

BMI, body mass index; values expressed in means ± SD. Pearson's chi-square test[1]. One-way ANOVA test, Tukey's test[2]. Fisher's exact test[3].

II ($p \leq 0.03$ and 95% CI: 3.1 to 22, 8), III ($p \leq 0.01$ and 95% CI: 1.7 to 20.1) and IV ($p \leq 0.002$ and 95% CI: 3.0 to 20.6). Group V was statistically lower than Group I ($p \leq 0.03$ and 95% CI: 0.52 to 17.6) (Table 2, Figure 1).

With respect to maximal respiratory pressures, the mean MIP in absolute values was 105.79 ± 27.10 $cmH_2O$, ranging from 50 to 196 $cmH_2O$ and as for relative values, a mean of 118.37 ± 31.41% was demonstrated, ranging from 53.02% to 218.51%. The MEP showed a mean value of 129.15 ± 32.97 $cmH_2O$ for absolute values, ranging from 60 to 254 $cmH_2O$ and for relative values, a mean of 118.82 ± 26.94% was demonstrated, ranging from 58.72% to 209.57%.

The groups had a homogeneous distribution regarding FEV1/FVC ratio, FEF25-75, MEP and MIP (absolute and relative values), with no significant differences (Table 2).

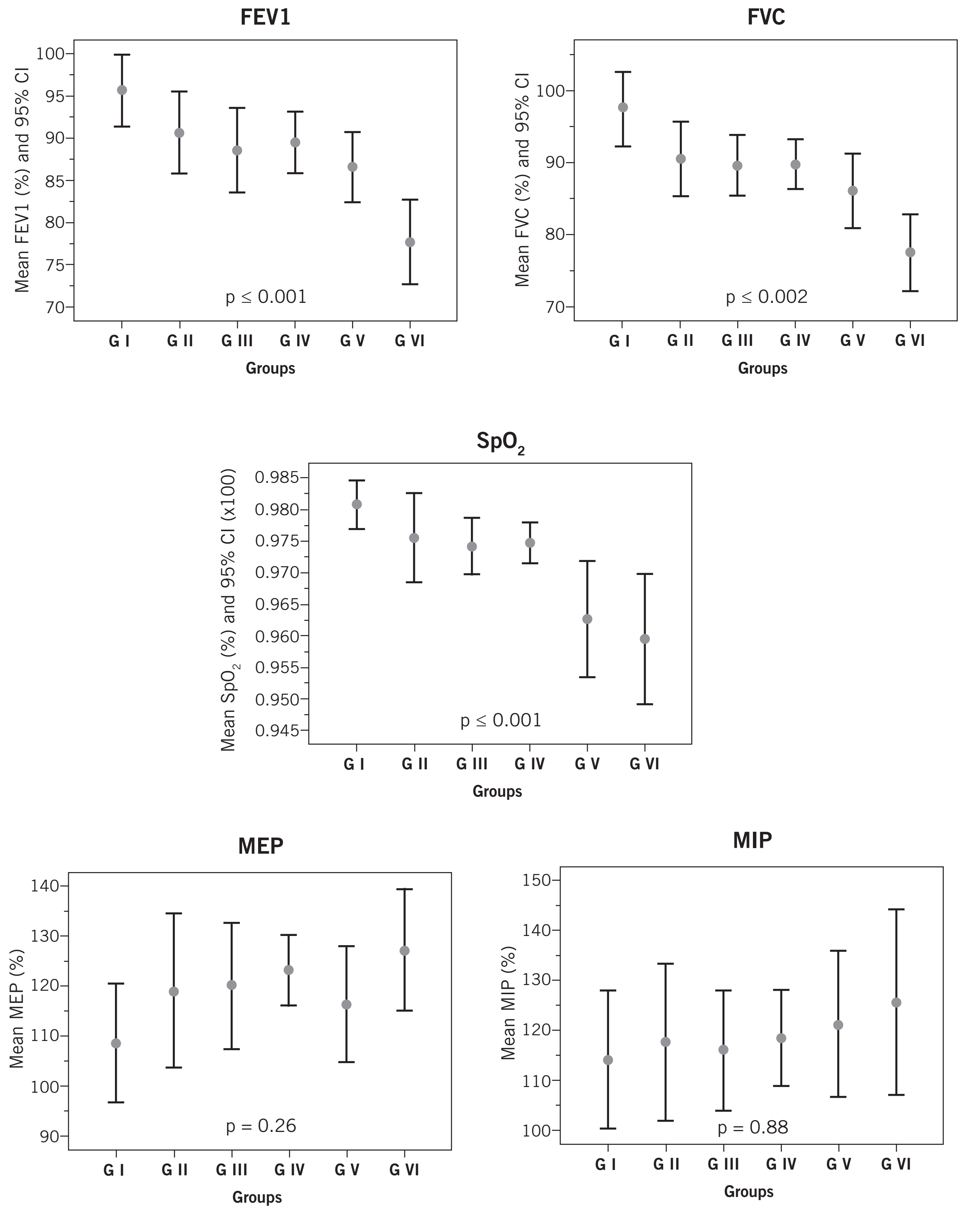
## Discussion

Previous studies evaluating lung function in obesity have generally considered the morbidly obese as a single group and only assessed lung function alterations in two

**Table 2** – Evaluation of spirometric variables, maximal respiratory pressures and oxygen peripheral saturation between the groups, stratified by BMI

| Variable (n) | G I (26) | G II (18) | G III (24) | G IV (30) | G V (23) | G VI (19) | p |
|---|---|---|---|---|---|---|---|
| FEV1, L | 3.39 ± 0.72 | 2.88 ± 0.43 | 3.02 ± 0.78 | 3.05 ± 0.67 | 3.06 ± 0.69 | 2.67 ± 0.76 | 0.03 |
| FEV1 % | 95.7 ± 10.5 | 90.6 ± 9.7 | 88.5 ± 11.8 | 89.5 ± 9.8 | 86.5 ± 9.5 | 77.6 ± 10.4 | 0.001 |
| FVC, L | 4.18 ± 0.86 | 3.56 ± 0.57 | 3.72 ± 0.85 | 3.73 ± 0.81 | 3.70 ± 0.90 | 3.20 ± 0.99 | 0.02 |
| FVC % | 97.4 ± 12.5 | 90.5 ± 10.4 | 89.5 ± 9.9 | 89.7 ± 9.2 | 86.1 ± 11.7 | 77.5 ± 11.1 | 0.002 |
| FEV1/FVC % | 81.1 ± 5.8 | 81.2 ± 6.6 | 80.9 ± 4.3 | 82.0 ± 4.9 | 83.1 ± 5.3 | 81.7 ± 5.0 | 0.72 |
| FEF25-75, L/s | 3.60 ± 1.22 | 3.57 ± 1.32 | 3.29 ± 1.20 | 3.47 ± 0.94 | 3.61 ± 0.95 | 3.02 ± 0.88 | 0.45 |
| FEF 25 / 75 % | 97.4 ± 23.4 | 107.9 ± 32.9 | 92.2 ± 22.0 | 98.6 ± 22.7 | 100.2 ± 22.2 | 88.8 ± 21.8 | 0.21 |
| MEP | 126.5 ± 39.3 | 120.2 ± 27.6 | 127.4 ± 32.4 | 131.1 ± 21.5 | 131.5 ± 41.8 | 137.6 ± 33.8 | 0.70 |
| MEP % | 108.6 ± 29.4 | 119.1 ± 30.8 | 120.0 ± 29.9 | 123.1 ± 19.0 | 116.4 ± 26.8 | 127.2 ± 25.2 | 0.26 |
| MIP | 102.4 ± 27.4 | 98.6 ± 19.6 | 105.1 ± 26.3 | 107.9 ± 23.8 | 109.4 ± 29.8 | 110.5 ± 35.6 | 0.73 |
| MIP % | 114.0 ± 34.1 | 117.4 ± 31.5 | 115.7 ± 28.5 | 118.4 ± 25.6 | 121.0 ± 33.7 | 125.4 ± 38.5 | 0.88 |
| $SpO_2$ | 98.1 ± 0.9 | 97.6 ± 1.4 | 97.4 ± 1.1 | 97.5 ± 0.9 | 96.3 ± 2.1 | 95.9 ± 2.1 | 0.001 |

Data expressed as absolute and relative values. Variables expressed as means ± sd. One-way ANOVA, Tukey's Test. BMI, body mass index.




$SpO_2$, peripheral oxygen saturation; FEV1, forced expiratory volume in one second; FVC, forced vital capacity; MEP, maximum expiratory pressure; MIP, maximum inspiratory pressure.

**Figure 1 –** Distribution of mean values and 95% CI of $SpO_2$, FEV1, FVC, MEP, MIP in relative values, between the groups, in the sample.

or three classes of obesity, without respiratory functional evaluation over all classes of obese individuals[6,13-15,19-21].

In this study, we aimed at demonstrating pulmonary function impairment secondary to the progressive increase in body weight in six BMI groups. We kept the WHO classification of obesity until the BMI ≤ 40 kg/m²; however, to differentiate our study from those previously reported, we established a control group of non-obese individuals and subdivided the group of morbidly obese patients into three subgroups, thus being able to observe the progressive impairment of respiratory function as BMI rises.

Our results demonstrated an inverse relationship between BMI and the respiratory functional variables studied, with a modest effect on lung function up to a BMI ≤ 45 kg/m², noting that Group IV (BMI 40 to 44.9 kg/m²) presented characteristics of respiratory function more similar to Groups II and III (obesity grade I and II) than the morbidly obese Groups V and VI (BMI ≥ 45 kg/m²).

Significant alterations in lung function were observed only when the BMI exceeded 45 kg/m², increasing when the BMI reached values above 50.9 kg/m², characterizing the group of morbidly obese patients as a heterogeneous group in terms of respiratory function, justifying its subdivision into subgroups for the assessment of lung function. These alterations differ from previous studies, which reported minimal changes in respiratory function up to the BMI ≤ 40 kg/m²; however, in these studies, the group of morbidly obese patients has always been considered as a single group (BMI ≥ 40 kg/m²)[3,6,19,22].

In recent years, there has been a marked increase in the number of obese patients undergoing surgical treatment of obesity. The good performance of inspiratory and expiratory muscles in the postoperative period of these patients is essential for the cough reflex and an adequate and effective tracheobronchial cleaning, contributing to good pulmonary oxygenation and ventilation[2,23,24].

There are controversies in the literature on the effect of obesity on maximal respiratory pressures[6,11,12]. Some studies state that the maximal respiratory pressures are usually normal in healthy individuals, in several degrees of obesity and particularly in morbidly obese individuals in the sitting position[6,11,25]. The reason is that obese individuals compensate for the respiratory load by doubling the respiratory effort and diaphragmatic pressure, increasing the contribution of the rib cage in the respiratory movement, by performing rapid and shallow breaths[11].

With an opposing view, Poulain et al.[26] reported that respiratory muscle strength may be impaired in obesity, with reduced maximal inspiratory pressure in the obese when compared with the non-obese control group, as a consequence of reduced chest wall compliance or lower lung volumes or both.

The results of the present study showed normal maximal respiratory pressures, with an upward trend as the BMI increases, although with a homogeneous distribution in the studied groups.

One limitation of a cross-sectional study such as this one is the lack of observation over time, not allowing determining prognostic considerations on the various subgroups of obese individuals.

## Conclusion

In conclusion, lung function is influenced by the progressive increase in BMI, with changes in lung function being better demonstrated when BMI ≥ 45 kg/m²; these changes in lung function are more evident when BMI > 50.9 kg/m².

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